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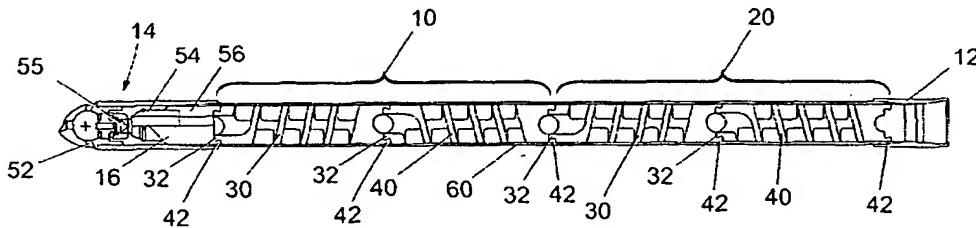
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(54) Title: CEMENT FLOW CONTROL TOOL



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(57) Abstract: An apparatus (10) for controlling the flow of fluid into a borehole through a conduit (60) is described. The apparatus has a decelerating means (30) adapted to be positioned within the conduit. The fluid could typically comprise drilling mud and/or cement, and in some embodiments, some of the cement can exit through apertures (84) in a shroud (82) of the apparatus to cement the decelerating means inside the conduit.

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CEMENT FLOW CONTROL TOOL

1

2

3 The present invention relates to a cement flow  
4 control tool and especially but not exclusively, a  
5 cement flow control tool for use in cementing a  
6 string of tubulars such as a casing or liner string  
7 into an oil, gas or water borehole.

8

9 Primary cementing is the process of placing cement  
10 in the annulus between a casing or liner string and  
11 the formations exposed to the borehole. A major  
12 objective of primary cementing is to provide zonal  
13 isolation in the borehole of oil, gas, and water  
14 wells, i.e. to exclude fluids such as water or gas  
15 in one zone from oil in another zone. To achieve  
16 this, a hydraulic seal must be obtained between the  
17 casing and the cement, and between the cement and  
18 the formations, while at the same time preventing  
19 fluid channels in the cement sheath. Without  
20 complete zonal isolation, the well may never reach  
21 its full producing potential and remedial work to

1 repair a faulty cementing job may do irreparable  
2 harm to the producing formation. In consequence,  
3 reserves may be lost and commencement of production  
4 may be delayed.

5

6 After drilling the well to the desired depth, the  
7 drillpipe is removed and a casing string is run in  
8 until it reaches the bottom of the borehole. The  
9 casing string typically has a shoe, such as a float  
10 shoe, guide shoe or a reamer shoe on the end to  
11 guide the casing string into the borehole. At this  
12 time, the drilling mud (used to remove formation  
13 cuttings during the drilling of the well) is still  
14 in the borehole; this mud must be removed and  
15 replaced by hardened cement.

16

17 This is done by passing cement down through the  
18 inside of the casing string; the cement passes out  
19 of apertures in the shoe and into the annulus  
20 between the borehole and the casing. The drilling  
21 mud is displaced upwards and the cement replaces it  
22 in the annulus. The cement needs to extend at least  
23 as far up the annulus so as to span the production  
24 zones, and the previous casing shoe if present, and  
25 sometimes the cement even extends to the surface.

26

27 However, the cement is heavy and so exerts a large  
28 force on the drilling mud. Drilling mud is less  
29 heavy than cement, so the cement causes the drilling  
30 mud to travel quickly up the annulus. Fast flowing  
31 drilling mud brings a high pressure to bear upon the  
32 formation and excess solids and drill cuttings may

1 build up in the annulus, exerting even more pressure  
2 on the formation. The formation may break down  
3 under the pressure, resulting in both severe mud  
4 loss and also a loss of production. Open hole  
5 sections of the formation are especially prone to  
6 collapse, possibly ruining the borehole.

7

8 An additional problem is that the cement, being  
9 heavier, may also fall down through the drilling  
10 mud, resulting in a poor cement job.

11

12 According to the present invention there is provided  
13 apparatus for controlling the flow of cement into a  
14 borehole through a conduit, the apparatus comprising  
15 a decelerating means adapted to be positioned within  
16 the conduit for slowing down the flow of fluid  
17 through the conduit.

18

19 The deceleration means typically controls or  
20 mitigates the free fall effect of the cement.

21

22 Preferably, the conduit is a drillpipe, tubing,  
23 coiled tubing, filtration screen, casing or liner  
24 string, but may be any conduit which is inserted  
25 into a borehole.

26

27 Typically, the decelerating means comprises a  
28 passage, and most preferably, the passage is defined  
29 by at least one body member having formations  
30 thereon.

31

1 Typically, the passage is inclined relative to the  
2 axis of the conduit and deceleration of the fluid is  
3 caused by friction between the fluid and the  
4 inclined passage. Typically, the passage is also  
5 inclined relative to a plane perpendicular to the  
6 axis of the conduit. Optionally, the inclination of  
7 the passage is continual throughout its length.

8

9 Typically, the inclined passage has constant  
10 dimensions and the boundaries of the passage are  
11 free of obstructions so that the fluid moves along  
12 the passage without hindrance.

13

14 The passage typically comprises portions with axial  
15 and transaxial components, so that the length of the  
16 passage is greater than the length of the apparatus.

17

18 The transaxial components of the passage typically  
19 cause the path of fluid flowing through the  
20 apparatus to deviate from its former axial path  
21 through the conduit prior to flowing through the  
22 apparatus, thereby decelerating the fluid.

23

24 Preferably, the decelerating means further comprises  
25 at least one spiral passage defined by the at least  
26 one body member.

27

28 The angle of the spiral portion of the passage is  
29 typically more than 60 degrees relative to the  
30 conduit axis, preferably between 70 and 80 degrees  
31 and most preferably around 75 degrees.

32

1 Preferably, the passage is uni-directional in the  
2 axial direction, so that in use, when fluid is  
3 flowing from the top to the bottom of the internal  
4 passage, no part of the passage would direct fluid  
5 up the apparatus.

6

7 Uni-directional embodiments have the advantage over  
8 other designs which include passages having  
9 upwardly-inclined portions and corresponding  
10 troughs, in which any suspension would be inclined  
11 to settle and block the passage.

12

13 Such uni-directional embodiments include those  
14 having a spiral passage; the continual slope of the  
15 spiral passage ensures that gravity can assist the  
16 flow of fluid through the passage. Embodiments  
17 incorporating the spiral design have the advantage  
18 that any suspended particles carried by the fluid  
19 will not settle in the passage and block the  
20 passage.

21

22 Optionally, the passage includes at least two  
23 portions spiralling in opposite directions to each  
24 other. Optionally, the spiral passage includes at  
25 least two of said portions and preferably oppositely  
26 directed spiralling portions are positioned adjacent  
27 one another.

28

29 Preferably, the passage includes two or more of said  
30 portions and most preferably, the passage is formed  
31 so that fluid travelling through a first portion  
32 will flow in a clockwise direction through the

1 spiralling parts of that portion, and fluid  
2 travelling through a second, neighbouring portion  
3 will flow in an anti-clockwise direction through its  
4 spiralling portion, or vice versa.

5

6 Typically, the decelerating means induces turbulence  
7 into the fluid to decelerate the fluid.

8

9 Optionally, the turbulence is wholly, mainly or  
10 partly induced by a direction-altering means, which  
11 changes the direction of fluid flowing in the  
12 internal passage. Typically, the direction-altering  
13 means comprises a cavity provided between first and  
14 second oppositely directed spiral passage portions,  
15 providing a space in which the fluid changes  
16 direction between the first spiral direction and the  
17 second spiral direction. The cavity is typically  
18 formed in the at least one body member and may  
19 comprise a connecting passage linking the spiral  
20 passage portions; the connecting passage may include  
21 axial portions and transaxial portions.

22

23 Whether turbulent or laminar flow results depends  
24 (among other parameters) on the speed of the fluid  
25 through the passage. Thus, in embodiments of the  
26 invention which induce turbulence, the apparatus can  
27 have a decelerating effect on some fluids but not on  
28 others, depending on the speed of the fluid. The  
29 turbulence will only have a significant effect upon  
30 fast flowing fluids and slow flowing fluids will not  
31 be appreciably slowed.

32

1   However, simple embodiments of the invention, which  
2   may comprise a member forming a simple spiral  
3   passage or an alternative form of passage inclined  
4   relative to the conduit axis, can optionally  
5   decelerate fluids without any inducing any  
6   significant turbulent effect.

7

8   Optionally, the spiral passage is tightly wound, so  
9   that the spiral passage is longer than the conduit  
10   in which it is positioned, and preferably  
11   considerably longer. The angle of the spiral  
12   passage in these tightly wound embodiments can be  
13   between 75 degrees and 90 degrees to the conduit  
14   axis. Such embodiments can cause fluids to be  
15   decelerated due to forcing the fluids to continually  
16   change direction in the (in use) horizontal plane  
17   orthogonal to the axis. As the fluids travel in the  
18   circular plane, they will typically collide with the  
19   outer wall of the conduit, or any sleeve or shroud  
20   surrounding the passage, and they will be  
21   decelerated by friction between the fluids and that  
22   interface. This can be in addition, or instead of,  
23   any turbulent effect.

24

25   As explained above, embodiments including a spiral  
26   passage have the advantage that gravity assists the  
27   flow of fluids along the passage and that any  
28   suspension in the fluids is prevented from settling  
29   out, due to the continuing slope of the passage.

30

31   Optionally, the body members connect by interlocking  
32   means, which may include tongues and grooves.

1  
2     Optionally, the at least one body member is cemented  
3     or otherwise fitted inside the casing or liner  
4     string.

5  
6     Typically, the apparatus is used in conjunction with  
7     equipment, such as a shoe and/or a float collar, at  
8     least one of which is provided with a valve  
9     (typically a one-way valve). Preferably, the cross-  
10    sectional area of the flow path through the passage  
11    is greater than the cross-sectional area of the flow  
12    path through the valve.

13  
14    If the valve is provided in the float collar, and in  
15    use, the float collar is located above the  
16    apparatus, then this prevents the apparatus from  
17    having a choke effect on any fluids passing through  
18    it. As the area of the passage is greater than that  
19    of the valve, the passage does not create a bigger  
20    restriction to the flow of fluid than has already  
21    been created by the valve and the fluid is not  
22    "choked" by the passage.

23  
24    Thus, in such embodiments, the rate of fluid leaving  
25    the shoe and the deceleration of the fluid is not  
26    limited by the cross-section of the passage, only by  
27    the amount of turbulence or other decelerating  
28    effect created by the apparatus.

29  
30    Optionally, the apparatus includes at least one  
31    collar attached to an end (preferably the lower end)  
32    of the casing or liner string, the collar having

1 screw threads for attachment to further sections of  
2 casing or liner.

3

4 The collar can replace the shoe at the (in use)  
5 lower end of the apparatus. The collar may couple  
6 the casing or liner tubular within which the  
7 apparatus is inserted to further casing or other  
8 equipment, in the case that another piece of  
9 equipment is required directly above the shoe.

10

11 A conventional coupling is typically used to attach  
12 the (in use) upper end of the casing or liner  
13 tubular within which the apparatus is located to the  
14 rest of the casing or liner string.

15

16 Preferably, the apparatus comprises an anti-rotation  
17 means to prevent relative rotation of the body  
18 members and thus the passage and the shoe.

19 Typically, the anti-rotation means includes a  
20 device, which may be a sub, shaped to engage a bore  
21 provided in the shoe. Preferably, an axial locking  
22 means is provided to prevent axial separation of the  
23 device and the shoe. Preferably, the axial locking  
24 means comprises a latch provided on one of the  
25 device and the shoe, and a groove (to engage the  
26 latch) provided on the other of the device and the  
27 shoe. Most preferably, the locking means comprises  
28 a circlip provided on the device which is adapted to  
29 engage a groove in the shoe to prevent axial  
30 separation of the device and the shoe. Preferably,  
31 the anti-rotation means comprises a tapered edge  
32 provided on one of the device and the shoe and a

1 correspondingly shaped groove provided on the other  
2 of the device and the shoe. Typically, the tapered  
3 edge is provided on the device and the groove is  
4 provided in the shoe. Typically, the anti-rotation  
5 means prevents relative rotation of the at least one  
6 body member and the shoe once the axial locking  
7 means has engaged.

8

9 The anti-rotation means is useful to help prevent or  
10 restrict the rotation of the at least one body  
11 member and thus the passage when the at least one  
12 body member is drilled through. Rotation of the  
13 passage would be disadvantageous as rotation of the  
14 drill bit could rotate the passage, if it is not  
15 firmly cemented to the casing, instead of drilling  
16 through the passage.

17

18 Optionally, the apparatus further comprises an outer  
19 protection means, which may be a shroud. Typically,  
20 the outer protection means is provided with  
21 apertures in the side wall thereof.

22

23 According to a second aspect of the present  
24 invention there is provided a control assembly,  
25 including:

26 control apparatus for controlling the flow of  
27 fluid into a borehole through a conduit, the  
28 apparatus comprising a decelerating means adapted to  
29 be positioned within the conduit for slowing down  
30 the flow of fluid through the conduit, the  
31 decelerating means comprising a passage in the  
32 apparatus;

1           a conduit in which the control apparatus is  
2 located; and

3           a valve located in the conduit above the  
4 apparatus;

5           wherein the cross-sectional area of the passage  
6 in the apparatus is greater than the cross-sectional  
7 area of the valve.

8

9 Preferably, the valve is located in a float collar.

10

11 According to a third aspect of the present invention  
12 there is provided a method of controlling the  
13 passage of fluid through a conduit located in a  
14 borehole, including the step of decelerating the  
15 fluid.

16

17 Optionally, the fluid is decelerated by being passed  
18 through a decelerating means located inside the  
19 conduit, the decelerating means being adapted to  
20 decelerate the fluid passing through the conduit.

21

22 Preferably, the decelerating means is inserted into  
23 the conduit prior to running in the conduit into the  
24 borehole.

25

26 Optionally, the deceleration is caused by the fluid  
27 being forced to change direction. Optionally, the  
28 method includes the step of causing the fluid to  
29 deviate from the conduit into a passage which is  
30 inclined relative to the conduit axis. Some, or  
31 all, of the decelerating effect could be caused by

1 friction as fluid travels along a passage in the  
2 apparatus.

3

4 Optionally, the fluid travels in a direction having  
5 a circular component, which is typically in the (in  
6 use) horizontal plane orthogonal to the axial  
7 direction.

8

9 Typically, the fluid is decelerated by causing it to  
10 travel through a passage, which may be a spiral  
11 passage, defined by the decelerating means. In use,  
12 the inclination of the spiral passage relative to  
13 the vertical enables gravity to aid the motion of  
14 the fluid through the passage, and means that any  
15 particles suspended in the fluids are unlikely to  
16 settle out in the passage to block the passage. The  
17 spiral may be tight, so that fluid will travel  
18 through a large distance in a small axial space.

19

20 Optionally, the fluid is decelerated by induction of  
21 turbulence into the fluid. This may be achieved by  
22 passing the fluid through a spiral passage including  
23 portions spiralling in opposite directions. In such  
24 embodiments, the turbulence may be induced in a  
25 connection region between the portions where fluid  
26 spiralling in one direction has to change direction  
27 and spiral in the opposite direction.

28

29 Typically, the spiral passage includes a plurality  
30 of oppositely directed spiralling portions  
31 positioned in series and the fluid passes through a

1 plurality of connection regions as it flows through  
2 the conduit.

3

4 Optionally, the amount of turbulence induced is  
5 dependent on the speed of the fluid flow, and the  
6 turbulence induced for slowly flowing fluids may be  
7 zero or negligible.

8

9 Typically, a float collar having a valve is provided  
10 in the conduit above the inclined passage, the  
11 passage having a greater cross-sectional area than  
12 the cross-sectional area of the valve so that the  
13 fluid flows without restriction into the passage.

14

15 Typically, a shoe is attached to one end of the  
16 conduit, the shoe having a fluid outlet, and fluid  
17 is pumped or passed through the conduit and enters  
18 the borehole by the fluid outlet.

19

20 Optionally, the inclined passage is defined by at  
21 least one body member having formations thereon and  
22 a shroud having apertures in its surface is provided  
23 around the body member, and the method includes the  
24 step of passing cement through the passage, some of  
25 which exits the passage via the apertures to cement  
26 the body member to the conduit.

27

28 An embodiment of the invention will now be described  
29 by way of example only and with reference to the  
30 following drawings, in which:-

31 Fig 1 shows a side view with interior detail of  
32 two cement tools stacked on top of each other

1 and inserted in a downhole assembly between a  
2 shoe and a casing string;  
3 Fig 2 shows a side view with interior detail of  
4 the shoe of Fig 1;  
5 Fig 3 shows a perspective view of a connector  
6 sub of Fig 1;  
7 Fig 4 shows a side view with interior detail of  
8 a collar which can be used with the tool of Fig  
9 1;  
10 Fig 5 shows a side view of a first tool  
11 portion;  
12 Fig 6 shows a side view of a second tool  
13 portion;  
14 Fig 7 shows a plan view of the rear (right  
15 hand) end of the second tool portion of Fig 6,  
16 rotated through 180°;  
17 Fig 8 shows a plan view of the front (left  
18 hand) end of the first tool portion of Fig 5;  
19 Fig 9 shows a side view with some interior  
20 detail exposed of one of the cement tools of  
21 Fig 1;  
22 Fig 10 shows a schematic diagram of the  
23 apparatus assembled in a borehole, with cement  
24 forcing the drilling mud through the apparatus;  
25 Fig 11 shows a schematic diagram of the  
26 apparatus with displacement fluid forcing the  
27 cement through the apparatus;  
28 Fig 12 shows a side view with interior detail  
29 of an alternative embodiment of the invention,  
30 including a tightly-wound spiral passage;  
31 Fig 13 shows a schematic diagram of the Fig 12  
32 embodiment of the invention located in a casing

1           string between a float collar and a float shoe;  
2           and

3           Fig 14 shows a schematic diagram of an  
4           alternative arrangement to Fig 13, having a  
5           spiral passage spiralling in one direction  
6           only.

7

8       Fig 1 shows apparatus in accordance with the present  
9       invention comprising a first cement tool 10 and a  
10      second cement tool 20 coupled together. Each tool  
11      10, 20 is made up of a first body member 30 having a  
12      left hand spiral portion and a second body member 40  
13      having a right hand spiral portion, shown in Figs 5,  
14      6, 7 and 8. It will, however, be appreciated that  
15      the left and right hand spiral portions may be  
16      swapped with one another.

17

18      The cement tools 10, 20 are located inside a length  
19      of casing 60, which has standard screw thread  
20      connections on each end. The upper end of casing 60  
21      is connected to a casing coupling 12 which is  
22      attached to the rest of the casing string (not  
23      shown). It is not necessary for the tools 10, 20 to  
24      be located inside casing 60; the tools 10, 20 may be  
25      located inside any conduit which is inserted into  
26      the borehole, such as drillpipe, tubing, coil tubing  
27      or liner. The cement tools 10, 20, do not  
28      necessarily extend all the way up the length of  
29      casing 60 as shown in Fig 1; the cement tools 10, 20  
30      typically only extend approximately halfway up the  
31      length of casing 60.

32

1    Each body member 30, 40 has a central column 31, 41  
2    with a spiral protrusion 34, 44 extending therefrom.  
3    The radially outer edge of the spiral protrusions  
4    34, 44 extends substantially to the inner wall of  
5    the casing 60. Thus, a spiral passage 36, 46 is  
6    formed between the surfaces of the spiral protrusion  
7    34, 44, the central column 31, 41 and the inner  
8    surface of the casing 60.

9

10   The body members 30, 40 are connected together by  
11   inter-engaging tongues and grooves. Each body  
12   member 30, 40 has a dove tail or tongue 32 at one  
13   end (here, the upper end with respect to the  
14   borehole) and a groove 42 in the opposite end.  
15   However, in some embodiments, the positions of the  
16   tongues 32 and the grooves 42 are reversed. Each  
17   tongue 32 is dimensioned so that it is a tolerance  
18   fit with its respective groove 42 so that the  
19   portions 30, 40, will not become accidentally  
20   disconnected in the borehole.

21

22   The cement tools 10, 20 are connected together in  
23   the same way as the body members 30, 40; i.e. by  
24   connecting the groove 42 of the second body member  
25   40 of the first tool 10 with the tongue 32 of the  
26   first body member 30 of the second tool 20. A  
27   connecting passage 86 joins the spiral passages 36,  
28   46 of the body members 30, 40 together, as best  
29   shown in Fig 9. The connecting passage 86 is  
30   preferably cylindrical, having a first axial portion  
31   88 which extends from the (in use lower) end of  
32   spiral passage 46, a second axial portion 89 which

1 extends from the (in use upper) end of the spiral  
2 passage 36 and a third transaxial portion 86A, 86B  
3 being a passage travelling through, and across the  
4 axis of, the cement tool 10, 20, connecting the  
5 first and second axial portions together. The first  
6 88 and second 89 axial passage portions are formed  
7 from a pair of off-centre axially arranged  
8 cylindrical bores formed respectively through the  
9 members 40, 30 and the third transaxial passage  
10 portion 86 is formed from a transaxially arranged  
11 cylindrical bore 86 formed through the body members  
12 30, 40 when joined together, so that the transaxial  
13 bore 86 spans the join between the body members 30,  
14 40.

15

16 In some embodiments, transaxial passage 86 may be  
17 inclined relative to the (in use) horizontal plane,  
18 so as to continue the inclined path of spiral  
19 passages 36, 46.

20

21 Fluid flowing through the cement tools 10, 20 will  
22 be decelerated by being forced to change from axial  
23 to spiral flow.

24

25 The lower end of casing 60 is connected to a shoe 14  
26 by means of standard screw threads. The cement tool  
27 10 is connected inside the shoe 14 by an anti-  
28 rotation connector sub 16 (shown in Fig 3). The  
29 connector sub 16 has a groove 42 which engages the  
30 tongue 32 of the lower end of the first cement tool  
31 10. The connector sub 16 has a front portion 54 and  
32 a rear portion 56. Both portions 54, 56 are

1   cylindrical but portion 56 has a larger diameter.  
2   The lower end of portion 56 tapers to a point to  
3   provide a tapered end 58. A circlip 62 is disposed  
4   in a groove in the front portion 54.

5

6   The shoe 14 has an inner bore shaped to co-operate  
7   with the outside surface of the connector sub 16.  
8   The inner bore has a narrow portion 68 with a groove  
9   64 for engagement of the circlip 62. The inner bore  
10   of the shoe 14 also has a wider portion 69 having a  
11   V-shaped receiving surface 70 corresponding to the  
12   tapered end 58 to receive the tapered end 58.

13

14   The connector sub 16 is inserted into the shoe 14  
15   and, once the circlip 62 is aligned with the groove  
16   64 in the inner bore of the shoe 14, the circlip 62  
17   expands into the groove 64. This prevents further  
18   axial movement between the shoe 14 and the connector  
19   16 (and hence the tools 10, 20 and the rest of the  
20   apparatus).

21

22   The connector sub 16 can be inserted at any angle,  
23   as it will align itself due to the tapered end 58  
24   mating with the V-shaped receiving surface 70. Once  
25   the circlip 62 is engaged, the tapered end 58 cannot  
26   escape from the V-shaped receiving surface 70 as the  
27   axial movement needed to do this is prevented by the  
28   engaged circlip 62. Furthermore, the connector sub  
29   cannot rotate relative to the shoe 14 due to the  
30   mating of the tapered end 58 and the V-shaped  
31   receiving surface 70. Therefore, the shoe 14 is

1 fixed relative to the cement tools 10, 20, both  
2 rotationally and axially.

3

4 The shoe 14 has a nose 50 having outlet ports 52 to  
5 allow fluids to pass through the shoe 14 into the  
6 annulus between the casing and the borehole (not  
7 shown). The shoe 14 also typically has a one-way  
8 valve 55, to prevent fluids from flowing back into  
9 the casing string.

10

11 The apparatus is typically used in conjunction with  
12 a float collar, as shown in Figs 10 and 11. In  
13 these figures, casing 60 (in which cement tools 10,  
14 20 are located) is shown coupled beneath a float  
15 collar 96. Float collar 96 can be a standard float  
16 collar which is commercially available; such float  
17 collars usually include a valve 105, which is  
18 typically a one-way valve. For safe operation of  
19 the equipment, a valve must be provided in at least  
20 one of the float collar 96 and the shoe 14.

21

22 The cross-sectional areas of the respective passages  
23 36, 46 inside the tools 10, 20 are preferably  
24 greater than the cross-sectional area of the valve  
25 105. This means that the fluid flow rate is not  
26 limited by the cross-sectional area of the passages  
27 36, 46. The fluid flow rate is only limited by the  
28 amount of turbulence created inside the tools 10,  
29 20. Therefore the cement tools 10, 20 do not  
30 "choke" the fluid, as they do not restrict the  
31 cross-sectional area through which it flows.

32

1 Fig 4 shows a collar 80 which can be attached to the  
2 cement tool 10, instead of the shoe 14. The collar  
3 80 is typically used in the cases where it is not  
4 desired to connect the tools 10, 20 directly to the  
5 shoe 14, e.g. if another tool is required to be  
6 inserted above the shoe 14. However, it will also  
7 be appreciated that the cement tools 10, 20 could be  
8 placed at any suitable position in the conduit by  
9 any suitable locating device such as adhesives etc.  
10 or even by providing the outer diameters of the  
11 cement tools 10, 20 as a clearance fit with the  
12 inner diameter of the conduit. Each end of the  
13 collar 80 is screw threaded for engagement with  
14 casing 60 and for engagement with further casing  
15 (not shown). The collar 80 has an inner bore  
16 similar to that of the shoe 14 for engagement with  
17 the connector sub 58. The inner bore has a narrow  
18 portion 68 with a groove 64 for engagement of the  
19 circlip 62 and a wide portion 69, having a tapered  
20 circumference 70 corresponding to the tapered end  
21 58. The collar 80 may be used to position the tools  
22 10, 20 above the shoe track 93 (the shoe track is  
23 shown in Figs 10 and 11). (The shoe track 93 is a  
24 common term in the industry to designate the  
25 combination of a shoe, one or two joints of casing  
26 and a float collar.)  
27

28 Fig 9 shows the tool 10 having a shroud 82 around  
29 the exterior, which could be formed from an easily  
30 drillable material. The shroud 82 has apertures 84  
31 formed in its side wall. The apertures 84 are

1 typically distributed throughout the surface of the  
2 shroud 82.

3

4 The shoe 14, the tools 10, 20, the connector sub 16,  
5 any collar 80 and any plugs used with the apparatus  
6 are preferably made from materials which can be  
7 drilled through, such as a plastic or aluminium.

8 The tools 10, 20 and connector sub 16 are preferably  
9 made out of a thermoplastic.

10

11 In use, the shoe 14, connector sub 16, tools 10, 20,  
12 casing 60 and casing coupling 12 are connected to  
13 form the assembly shown in Fig 1 by engaging screw  
14 threads, tongues and grooves as described above.

15 The assembly is then run into the borehole and  
16 drilling mud is pumped down through the casing  
17 string. When the assembly reaches the required  
18 depth, the casing is cemented in place. This is  
19 done by pumping cement down through the casing  
20 string. The cement is pumped on top of the drilling  
21 mud already in the casing string, and displaces the  
22 drilling mud, accelerating the mud down through the  
23 casing string and the tools 10, 20.

24

25 The cement may be pumped directly on top of the  
26 drilling mud, in which case it could be advantageous  
27 to start with a low density cement slurry and to  
28 gradually build up the density. Cement additives  
29 (commercially available) have been developed to  
30 control the density of the cement slurry. The  
31 density can be lowered by adding an additive which  
32 has a low specific gravity, or which allows large

1 quantities of water (which is lighter weight than  
2 cement) to be added to the cement, or a combination  
3 of both. The lead slurry should therefore be the  
4 lightest; typically around 10 lb/gallon, followed by  
5 an intermediate slurry of around 11.5 lb/gallon, and  
6 a tail slurry of 15 lb/gallon.

7

8 In this way, full density cement is not directly on  
9 top of the drilling mud, and this reduces the  
10 probability of the cement falling through the mud.  
11 The decelerating action of the tools 10, 20, which  
12 will be detailed subsequently, also reduces the  
13 likelihood that the cement will fall through the  
14 mud.

15

16 Alternatively, as shown in Fig 10, a plug 90 could  
17 be positioned between the drilling mud 94 and the  
18 cement 92. The plug 90 typically has a sheer  
19 section 91 which breaks on the application of a  
20 threshold pressure. In the case where the tools 10,  
21 20 are located directly on top of the shoe 14, the  
22 plug 90 lands on top of the float collar 96. Fig 11  
23 shows the plug 90 landed and sheared by the pressure  
24 of the cement 92 above it. The float collar 96  
25 typically has an anti-rotation device (not shown),  
26 such as saw tooth protrusions, to engage the plug 90  
27 and to prevent rotation of the plug 90 when it is  
28 subsequently drilled through.

29

30 The Fig 10 embodiment also shows the casing 60  
31 (which contains the cement tools 10, 20) and a  
32 following casing string 61 having commercially

1 available centralisers 98 to hold the casing 60 and  
2 the casing string 61 in the centre of the borehole  
3 95.

4

5 In the case (not shown) where the tools 10, 20 are  
6 located above the shoe track 93 such that the tools  
7 10, 20 would be located in the casing string 61, a  
8 landing device (not shown) is typically provided to  
9 land the plug 90. The landing device would  
10 typically have an anti-rotation device to prevent  
11 rotation of the plug, as explained above.

12

13 Before the cement puts pressure on the drilling mud,  
14 the drilling mud flows slowly enough through the  
15 tools 10, 20 for the flow to be laminar. The flow  
16 of the drilling mud is not choked by the apparatus,  
17 because the cross-sectional areas of passages 36, 46  
18 are greater than the cross-sectional area of the  
19 valve 105 in the float collar 96. Thus, the tools  
20 10, 20 do not restrict the flow of the drilling mud  
21 before the cement is introduced into the casing  
22 string; the only restriction on the flow of the  
23 drilling mud is the size of the valve 105.

24

25 However, when the mud is accelerated by the cement,  
26 the velocity of the mud is increased sufficiently  
27 for the drilling mud to become turbulent. As the  
28 drilling mud passes from the right-hand spiral  
29 portion 40 to the left-hand spiral portion 30, the  
30 drilling mud is forced to spiral in the opposite  
31 direction. Anticlockwise spiralling mud meets  
32 clockwise spiralling mud in the passage 86 between

1 the portions 30, 40 such that eddy currents build up  
2 and the mud in the passage becomes turbulent. The  
3 turbulence restricts the flow of the mud through the  
4 tools 10, 20. Thus, the velocity of the mud which  
5 leaves the shoe and flows up the annulus between the  
6 casing and the formation is reduced, thereby  
7 exerting a reduced pressure on the formation and  
8 reducing the probability of the formation breaking  
9 down.

10

11 When the cement reaches the tools 10, 20, some of  
12 the cement flows through the apertures 84, which  
13 serves to cement the tools 10, 20 to the casing 60.

14

15 Cement is continued to be pumped through the casing  
16 string until all the drilling mud 94 has been  
17 expelled from the shoe 14 and the cement 92 now  
18 fills the annulus between the casing string 61 and  
19 the borehole 95. A plug 102 (see Fig 11) is  
20 typically used to act as a separator between the  
21 cement 92 and a displacement fluid 100 (e.g. more  
22 drilling mud) used to propel the cement 92  
23 downwards. Typically, this plug 102 lands on the  
24 float collar 96 (or the landing device, if the tools  
25 10, 20 are located above the float collar 96), on  
26 top of any previous plug 90. Thus, when the cement  
27 92 sets, in addition to filling the annulus, it will  
28 also fill all of the apparatus below the plug,  
29 including the tools 10, 20.

30 If deeper drilling is required, any plugs, the tools  
31 10, 20, any collar 80 and the shoe 14 are drilled  
32 through.

1  
2 Modifications and improvements can be made without  
3 departing from the scope of the invention. For  
4 example, more or fewer tools 10, 20 may be used, in  
5 combination. The plastic or aluminium shroud 82 and  
6 the anti-rotation connector sub 16 are not essential  
7 elements of the invention. For instance, the tools  
8 10, 20 could be cemented into the casing 60, or  
9 otherwise fixed to the casing 60 or the casing  
10 coupling 12; thus obviating the need for the anti-  
11 rotation connector sub 16.

12  
13 Also, left-hand and right-hand spiral portions 30,  
14 40 need not be positioned alternately; two portions  
15 30 could be followed by two portions 40. The tool  
16 could optionally comprise only one spiral portion,  
17 or a combination of uni-directional spiral portions.  
18 In further alternative embodiments, the spiral  
19 portions 30, 40 could be replaced by a combination  
20 of straight axially arranged portions (not shown)  
21 and circumferentially arranged portions (not shown)  
22 such that the fluid would flow around a  
23 circumferential portion at one height and then flows  
24 down the straight axially arranged portion to the  
25 next lower circumferential portion and so on.

26  
27 Furthermore the spiral portions 30, 40 need not be  
28 attached by tongues and grooves; other attachment  
29 means such as screw threads could be provided.  
30 The shoe 14 could be any type of shoe such as a  
31 reamer shoe, a guide shoe or a float shoe.

1 The anti-rotation sub 16 is not an essential feature  
2 of the invention. In some embodiments, it is not  
3 necessary, e.g. the cement tools 10, 20 can be  
4 cemented, jammed or secured in any other way to the  
5 inside of the casing or other conduit so as to  
6 prevent rotation.

7

8 In the case where the cement tools 10, 20 are  
9 located inside drillpipe, neither the shoe 14 nor  
10 the collar 80 would be necessary. The drillpipe  
11 could be hung off (i.e. from a casing string) in  
12 such a way as to prevent rotation of the drillpipe.  
13 The cement tools 10, 20 could be dimensioned to be a  
14 clearance fit inside the drillpipe, to jam the tools  
15 10, 20 inside the drillpipe to prevent relative  
16 rotation therebetween.

17

18 The passage 86 between spiral portions 30 and 40  
19 could include a chamber wider than the rest of the  
20 passage in which the streams of oppositely flowing  
21 fluid could meet and interact.

22

23 A further modification is shown in Fig 12, which  
24 shows an modified cement tool 110 inserted inside a  
25 casing length 122. Casing coupling 12 is also  
26 shown; casing coupling 12 is the same as that shown  
27 in Fig 1, and therefore the same reference number  
28 has been used.

29

30 Like the cement tools 10, 20 of the Fig 1  
31 embodiment, cement tool 110 has a central column 112  
32 with a spiral protrusion 114 extending therefrom.

1 Spiral protrusions 114 extend substantially to the  
2 inner wall of the casing 122 and define a spiral  
3 passage 116 between the surfaces of the spiral  
4 protrusion 114, the central column 112 and the inner  
5 surface of casing 122. The spiral is typically  
6 tightly wound, so that spiral passage 116 is longer  
7 than the axial length of cement tool 110. Spiral  
8 passage 116 spirals clockwise when viewed from the  
9 (in use) upper end of cement tool 110.

10

11 As in the Fig 1 embodiment, the spiral passage 116  
12 permits gravity to aid the flow of fluids along the  
13 passage, and reduces the chance of any suspended  
14 particles carried by the fluid settling out and  
15 blocking the passage.

16

17 It can be beneficial if the cross-sectional area of  
18 spiral passage 116 is greater than the cross-  
19 sectional area of a typical float collar valve. In  
20 such embodiments, the passage 116 does not limit or  
21 choke the flow of fluids when used in combination  
22 with a float collar having a valve. However,  
23 alternative embodiments of the invention can have a  
24 passage with a smaller cross-sectional area than  
25 that of a float collar valve.

26

27 Although only one cement tool 110 is shown in Fig  
28 12, it will be appreciated that this could be  
29 attached to one or more further cement tools, e.g.  
30 by interlocking tongues and grooves, as shown in the  
31 Fig 1 embodiment. The further cement tool may have

1 a passage which spirals in a clockwise or  
2 anticlockwise direction.

3

4 Fig 13 shows a schematic diagram of an assembly  
5 including two types of cement tool 110, 140. In  
6 this embodiment, two lengths of casing 122, 120 are  
7 connected together between float collar 96 and shoe  
8 14. However, the invention is not limited to use in  
9 conjunction with either a float collar or shoe.

10

11 Cement tool 110 is the one shown in detail in Fig  
12 12. Cement tool 140 is similar to cement tool 110,  
13 also having spiral protrusions 114 which define a  
14 spiral passage 116. However, the direction of  
15 spiral passage in cement tool 140 is reversed; this  
16 passage is spiralling anticlockwise when viewed from  
17 the (in use) upper end of the cement tool.

18

19 A first pair of cement tools 110, 140 are connected  
20 together; these are also connected to a second pair  
21 of cement tools 110, 140. In this embodiment, each  
22 cement tool 110, 140 is half as long as a length of  
23 casing, so that the two pairs of cement tools 110,  
24 140 fill both casing lengths 120, 122. In this  
25 schematic diagram, diagonal lines indicate the  
26 spiral protrusions 114 and the direction of spiral,  
27 but the full details of the cement tools 110, 140  
28 are not shown.

29

30 However, it will be appreciated that the length of  
31 each cement tool 110 is not important, and a greater  
32 number of shorter cement tools, or a smaller number

1 of longer cement tools could equally be used. A yet  
2 alternative arrangement is shown in schematic form  
3 in Fig 14, wherein a single, longer cement tool 150  
4 is located inside casing length 120. Cement tool  
5 150 is of the same form as cement tool 110 shown in  
6 detail in Fig 12, only longer. Thus, this  
7 embodiment causes fluid to spiral in one direction  
8 only. In this embodiment, no cement tool is located  
9 inside casing 122, which is empty.

10

11 As with the Fig 1 embodiment, a shroud (see Fig 9)  
12 can optionally be provided around cement tool 110,  
13 although this detail is not shown in Figs 12 to 14.

14

15 In the embodiments of Figs 12 to 14, spiral passage  
16 116 between spiral protrusions 114 is long and  
17 tightly wound. Therefore, the total length of  
18 spiral passage (i.e. made up of the combined lengths  
19 of the passages 116 of all of the cement tools 110,  
20 140 used) is considerably longer than (and may be  
21 many times as long as) the length of casing in which  
22 the cement tools 110, 140 are located.

23

24 In use, cement tools 110, 140 are fitted together  
25 and assembled inside the casing lengths 122, 120 as  
26 required between float shoe 14 and float collar 96.  
27 Cement is then pumped down the inside of the casing.  
28 The details of this are the same as described above  
29 with reference to the previous embodiment, e.g. the  
30 first portion of cement is typically low density  
31 cement slurry, and the density is then gradually  
32 built up to full density to reduce the likelihood of

1 the cement "falling through" the drilling mud.  
2 Alternatively or additionally, a plug with a sheer  
3 section (such as plug 90 in Fig 10) can be used to  
4 keep the cement and the drilling mud separate until  
5 plug 90 lands on float collar 96.

6

7 The cement pushes the drilling mud through the  
8 cement tools 110, 140. The drilling mud is forced  
9 to continually change direction to follow the spiral  
10 passage 116. The tighter the spiral, the greater  
11 the decelerating effect. Friction with the inside  
12 of the casing (or optional protective shroud) and  
13 spiral protrusions 114 decelerates the drilling mud.  
14 Thus, the embodiments shown in Figs 12 to 14 can  
15 decelerate a fluid with or without any additional  
16 deceleration caused by turbulence.

17

18 The drilling mud is propelled out of shoe 14 and up  
19 the annulus between the outside of casing lengths  
20 122, 120 and the borehole. However, as its speed  
21 has been reduced by cement tools 110, 140, the  
22 pressure on the formation is eased, rendering the  
23 formation less likely to collapse.

1    Claims

2

3    1. Apparatus for controlling the flow of fluid  
4    into a borehole through a conduit, the apparatus  
5    comprising a decelerating means adapted to be  
6    positioned within the conduit for slowing down the  
7    flow of fluid through the conduit.

8

9    2. Apparatus as claimed in claim 1, wherein the  
10   decelerating means comprises a passage in the  
11   apparatus.

12

13   3. Apparatus as claimed in claim 2, wherein the  
14   passage is defined by at least one body member  
15   having formations thereon.

16

17   4. Apparatus as claimed in claim 3, including a  
18   shoe adapted for engagement with the at least one  
19   body member.

20

21   5. Apparatus as claimed in claim 4, including an  
22   anti-rotation means to prevent relative rotation of  
23   the at least one body member and the shoe.

24

25   6. Apparatus as claimed in claim 5, wherein the  
26   anti-rotation means includes a device shaped to  
27   engage a bore provided in the shoe.

28

29   7. Apparatus as claimed in claim 5 or claim 6,  
30   wherein the anti-rotation means comprises a tapered  
31   edge provided on one of the device and the shoe and

1 a correspondingly shaped groove provided on the  
2 other of the device and the shoe.

3

4 8. Apparatus as claimed in claim 6 or claim 7 when  
5 dependent on claim 6, including an axial locking  
6 means to prevent axial separation of the device and  
7 the shoe.

8

9 9. Apparatus as claimed in claim 8, wherein the  
10 axial locking means comprises a latch provided on  
11 one of the device and the shoe, and a groove  
12 provided on the other of the device and the shoe.

13

14 10. Apparatus as claimed in claim 8 or claim 9 when  
15 dependent on claim 5, wherein the anti-rotation  
16 means prevents relative rotation of the at least one  
17 body member and the shoe once the axial locking  
18 means has engaged.

19

20 11. Apparatus as claimed in any of claims 3 to 10,  
21 wherein the apparatus includes a shroud which is  
22 disposed around the at least one body member.

23

24 12. Apparatus as claimed in claim 11, wherein the  
25 shroud is provided with apertures in the side wall  
26 thereof.

27

28 13. Apparatus as claimed in any of claims 2 to 12,  
29 used in conjunction with equipment having at least  
30 one valve, wherein the cross-sectional area of the  
31 passage is greater than the cross-sectional area of  
32 the at least one valve.

1 14. Apparatus as claimed in any of claims 2 to 13,  
2 wherein the passage has constant dimensions.

3

4 15. Apparatus as claimed in any of claims 2 to 14,  
5 wherein the boundaries of the passage are smooth and  
6 free of obstructions.

7

8 16. Apparatus as claimed in any of claims 2 to 15,  
9 wherein the passage is inclined relative to the axis  
10 of the conduit and wherein deceleration of the fluid  
11 is caused by friction between the fluid and the  
12 inclined passage.

13

14 17. Apparatus as claimed in any of claims 2 to 16,  
15 wherein the passage is inclined relative to a plane  
16 perpendicular to the axis of the conduit.

17

18 18. Apparatus as claimed in claim 16 or claim 17,  
19 wherein the inclination of the passage is continual  
20 throughout the length of the passage.

21

22 19. Apparatus as claimed in any of claims 2 to 18,  
23 wherein the passage is uni-directional in the axial  
24 direction.

25

26 20. Apparatus as claimed in any of claims 2 to 19,  
27 wherein the passage includes at least one spiral  
28 portion.

29

30 21. Apparatus as claimed in claim 20, wherein the  
31 angle of the spiral portion of the passage is more  
32 than 60 degrees relative to the axis of the conduit.

- 1
- 2    22. Apparatus as claimed in claim 20 or claim 21,  
3    wherein the angle of the spiral portion of the  
4    passage is between 70 degrees and 80 degrees  
5    relative to the axis of the conduit.
- 6
- 7    23. Apparatus as claimed in any of claims 2 to 22,  
8    wherein the passage includes at least one portion  
9    which spirals in a first spiral direction and at  
10   least one further portion which spirals in a second  
11   opposite spiral direction.
- 12
- 13   24. Apparatus as claimed in claim 23, wherein a  
14   cavity is provided between the at least two  
15   oppositely directed spiral passage portions,  
16   providing a space in which the fluid changes  
17   direction between a first spiral direction and a  
18   second spiral direction.
- 19
- 20   25. Apparatus as claimed in any preceding claim,  
21   wherein the decelerating means is adapted to induce  
22   turbulence into the fluid.
- 23
- 24   26. Apparatus as claimed in claim 25, wherein the  
25   turbulence is at least partially induced by a  
26   direction altering means which causes a change in  
27   the flow direction.
- 28
- 29   27. Apparatus as claimed in claim 25 or claim 26  
30   when dependent on claim 25, wherein the turbulence  
31   is induced in the cavity between the at least two  
32   oppositely-directed spiral passage portions.

1

2    28. Apparatus as claimed in any preceding claim,  
3    wherein the conduit comprises drillpipe, tubing,  
4    coiled tubing, filtration screen, casing or liner  
5    string.

6

7    29. A control assembly, including:  
8         control apparatus for controlling the flow of  
9         fluid into a borehole through a conduit, the  
10      apparatus comprising a decelerating means adapted to  
11      be positioned within the conduit for slowing down  
12      the flow of fluid through the conduit, the  
13      decelerating means comprising a passage in the  
14      apparatus;  
15         a conduit in which the control apparatus is  
16      located; and  
17         a valve located in the conduit above the  
18      apparatus;  
19         wherein the cross-sectional area of the passage  
20      in the apparatus is greater than the cross-sectional  
21      area of the valve.

22

23    30. An assembly as claimed in claim 29, wherein the  
24      valve is located in a float collar.

25

26    31. A method of controlling the passage of fluid  
27      through a conduit located in a borehole, including  
28      the step of decelerating the fluid.

29

30    32. A method as claimed in claim 31, including the  
31      step of causing the fluid to deviate from the

1 conduit into a passage which is inclined relative to  
2 the conduit axis.

3

4 33. A method as claimed in claim 32, wherein the  
5 fluid is decelerated by friction between the fluid  
6 and the boundaries of the inclined passage.

7

8 34. A method as claimed in claim 32 or 33, wherein  
9 the inclined passage has constant dimensions and the  
10 boundaries of the passage are free of obstructions  
11 so that the fluid moves along the passage without  
12 hindrance.

13

14 35. A method as claimed in any of claims 31 to 34,  
15 including the step of causing the fluid to travel in  
16 a spiral direction.

17

18 36. A method as claimed in claim 35, wherein the  
19 fluid is caused to travel in a tight spiral so that  
20 it travels through a large distance in a small axial  
21 space.

22

23 37. A method as claimed in claim 35 or claim 36,  
24 wherein the fluid is caused to travel in a first  
25 spiral direction and subsequently in a second  
26 opposite spiral direction.

27

28 38. A method as claimed in any of claims 32 to 37  
29 when dependent on claim 32, wherein a float collar  
30 having a valve is provided in the conduit above the  
31 inclined passage, and wherein the passage has a  
32 greater cross-sectional area than the cross-

1 sectional area of the valve so that the fluid flows  
2 without restriction into the passage.

3

4 39. A method as claimed in any of claims 31 to 38,  
5 including the step of inducing turbulence into the  
6 fluid.

7

8 40. A method as claimed in claim 39 when dependent  
9 on claim 38, wherein the turbulence is induced by  
10 causing the fluid to change direction from the first  
11 spiral direction to the second spiral direction.

12

13 41. A method as claimed in any of claims 32 to 40,  
14 wherein the inclined passage is defined by at least  
15 one body member having formations thereon and  
16 wherein a shroud having apertures in its surface is  
17 provided around the body member, the method  
18 including the step of passing cement through the  
19 passage, some of which exits the passage via the  
20 apertures to cement the body member to the conduit.

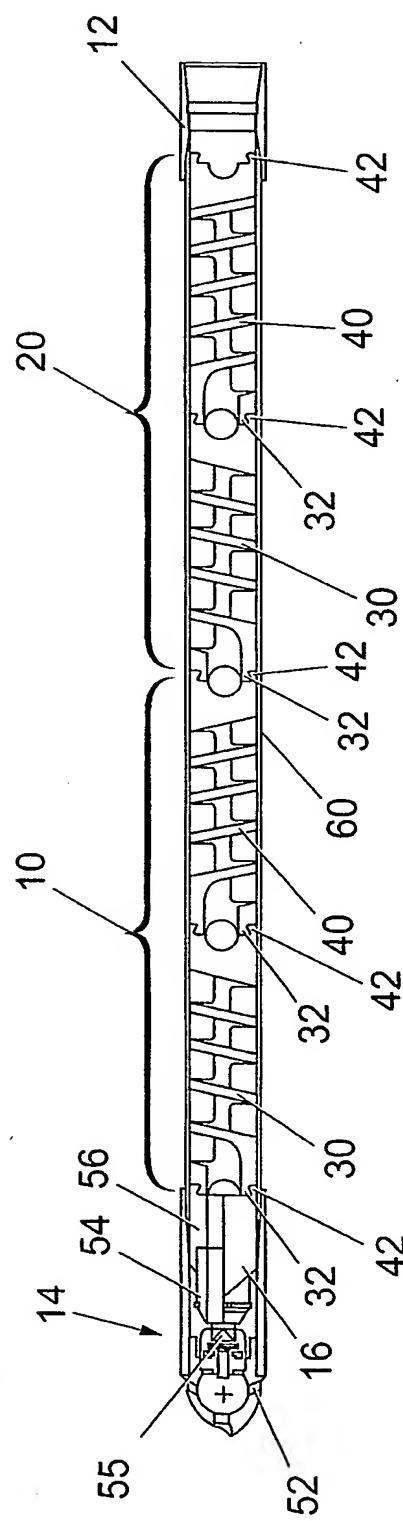


Fig. 1

Fig. 2

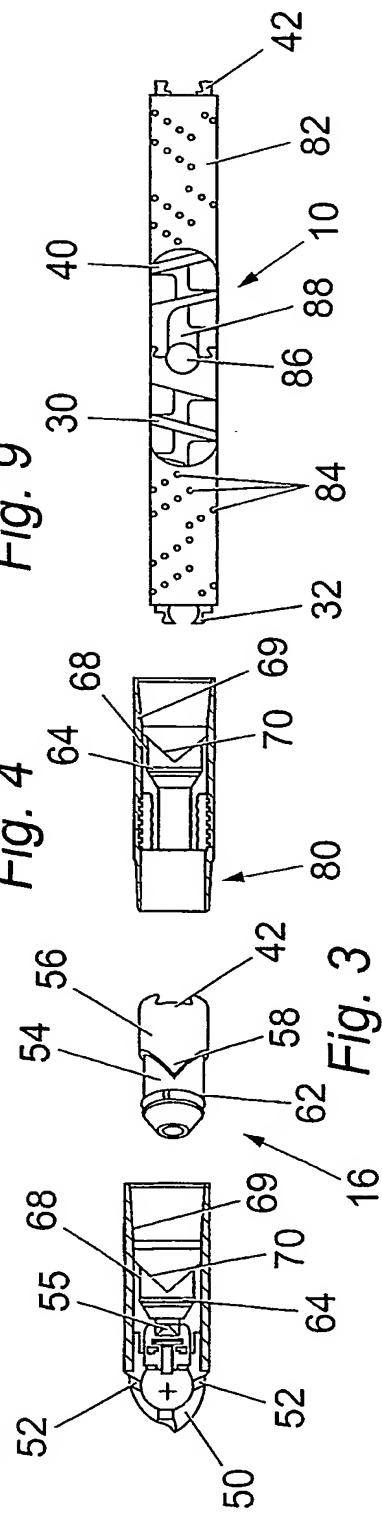


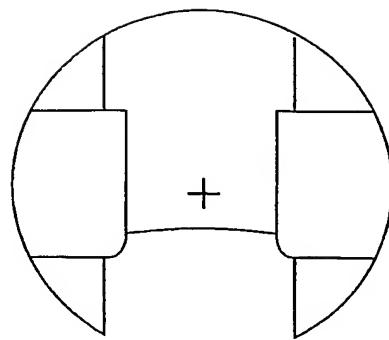
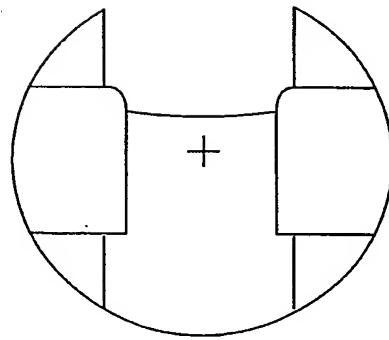
Fig. 9

Fig. 4

54

6

52

*Fig. 8**Fig. 7*

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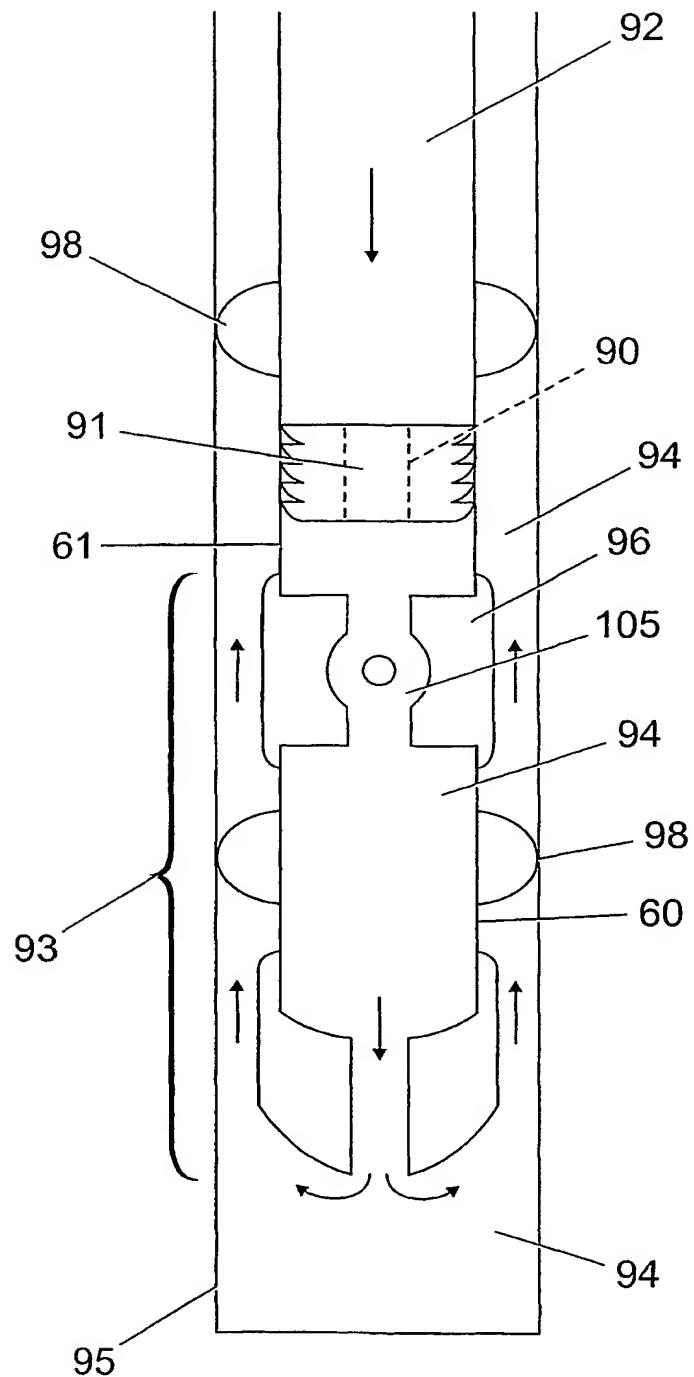


Fig. 10

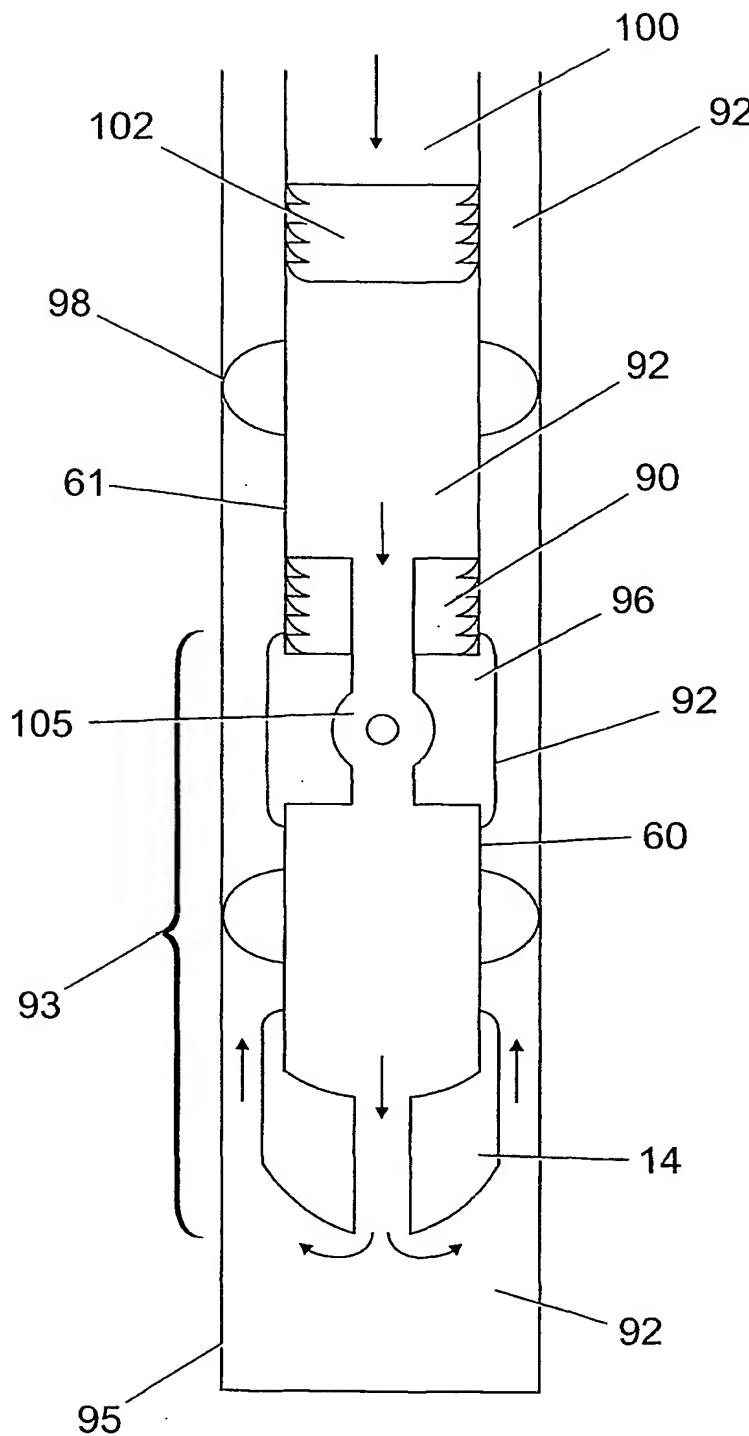


Fig. 11

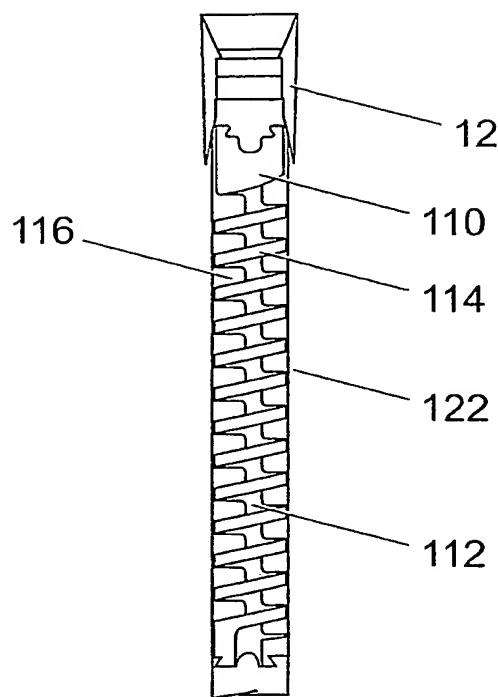


Fig. 12

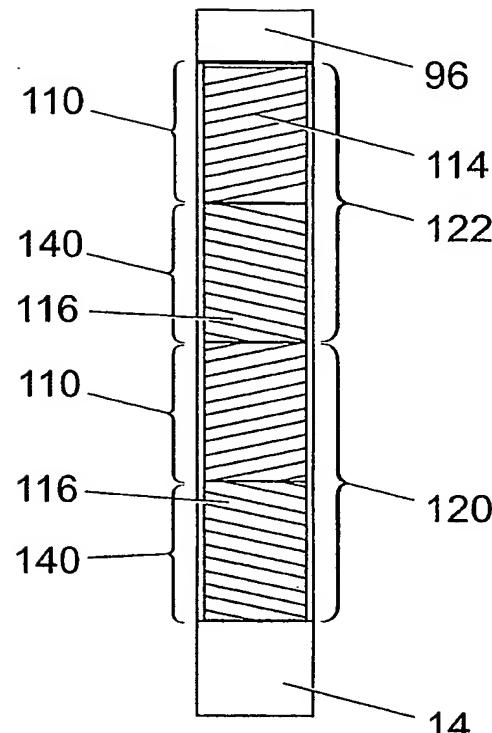


Fig. 13

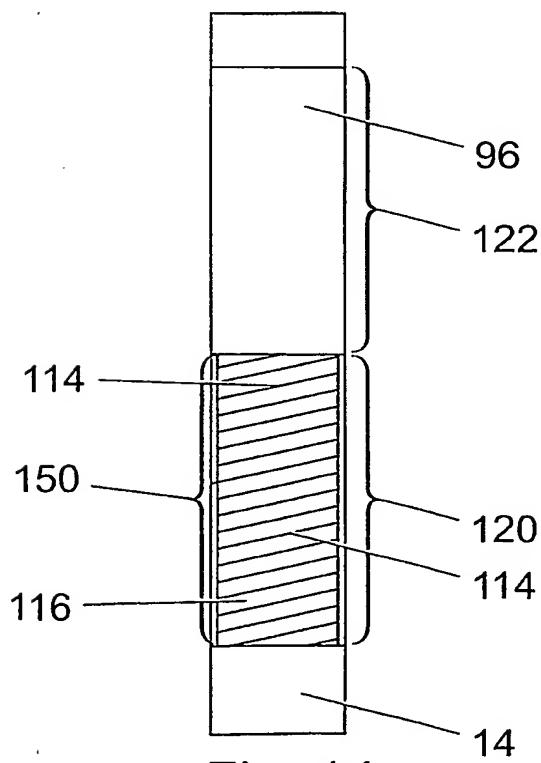


Fig. 14

## INTERNATIONAL SEARCH REPORT

PCT/GB 03/04588

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 E21B33/14

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 178 846 A (BAKER REUBEN C) 7 November 1939 (1939-11-07)  column 1, line 31 - line 45; figure 1 ---	1-6, 8, 10, 13-22, 25, 26, 28, 31-36, 38, 39
A	US 3 351 136 A (NELSON FRED B) 7 November 1967 (1967-11-07) column 2, line 16 - line 39 ---	1, 31
A	US 1 959 368 A (BENTON KENNEDYE CHARLES) 22 May 1934 (1934-05-22) the whole document ---	1, 31



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
13 February 2004	03/03/2004
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl. Fax (+31-70) 340-3016	Authorized officer  Ott, S

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## INTERNATIONAL SEARCH REPORT

PCT/GB 03/04588

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2178846	A	07-11-1939	NONE	
US 3351136	A	07-11-1967	NONE	
US 1959368	A	22-05-1934	NONE	

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